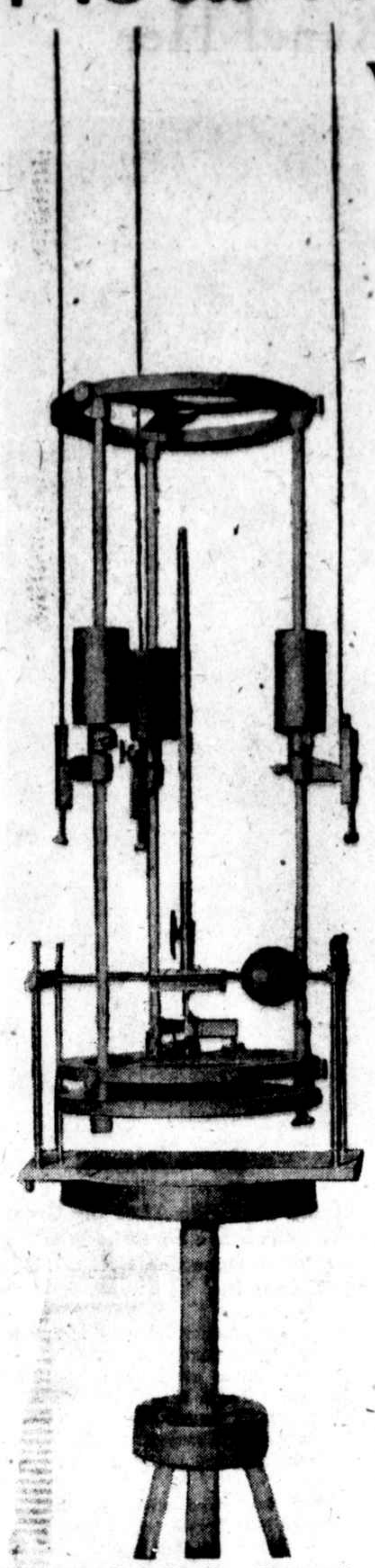
How They Weighed The Earth

Wonderfully Delicate Instrument Which Shows That Our Globe Tips the Scales at 12,000,000,000,000,000,000,000,000 —Twelve Septillion Pounds!



Photograph of the Extremely Delicate Mechanism in the Massachusetts Institute of Technology Laboratory; a Machine Devised Especially for Weighing the Earth.

SCIENTISTS are actually able to weigh the globe upon which we live. With the aid of quartz threads so delicate that they are barely visible to the naked eye they swing the earth in their scales and determine its weight almost as accurately as the butcher does with the roast for your Sunday dinner.

The latest weighing of the earth took place in the physics laboratory of the Massachusetts Institute of Technology, at Cambridge, Mass. The globe which man calls home tipped the scales at 6,000,000,000,000,000,000,000 tons—twelve septillion pounds—a mass so stupendous that the human mind can hardly comprehend it.

To weigh the earth scales quite different from those that serve for other purposes are employed. They consist of a delicate apparatus about the size of a sewing machine, whose operation depends upon the laws of gravitation discovered long ago by the great scientist, Sir Isaac Newton.

It was Newton who discovered that all objects are attracted by all other objects. Before his time men had believed that an apple fell to the ground merely because the air beneath it was too thin to support it. Newton showed plainly that the fall of the apple was caused by the attraction between the earth and the apple. The apple, being so much smaller than this globe of ours, naturally moved first.

This brought him to another conclusion, namely, that the attraction between two bodies depended directly upon their relative sizes—that is, that a piece of lead one cubic inch in volume was attracter toward the earth only one-half as strongly as a piece twice as large. Ordinarily we use the word "weight" to express this attraction between the earth and objects on its surface. And, as every one knows, the "weight" of an object increases with its size.

It was this rule of proportional attraction of which the Technology physicists, headed by Professor Louis E. Derr, made use in their latest experiment to determine the mass, or weight, of the earth itself.

They took two small brass balls, which they weighed to the fineness of one one-thousandth part of a gram. These balls they attached to threads drawn from melted quartz, threads so delicate that their size was only one-twelfth that of a human hair. By these threads the balls were suspended from the ends of a brass rod about the size of a lead pencil.

The rod itself was supported at its centre by a third thread, also of quartz. To this thread was attached a tiny mirror, which was arranged in such a way as to reflect a tiny spot of light upon the wall, forty feet distant. It is easily seen that a slight twisting of the thread which bore the mirror would be shown by the movement, greatly increased by the distance, of the little spot of light upon the wall.

Diagram Showing the True Proportionate Size of Atlas and the Earth from the Knowledge of Modern Science That the Density and Weight of the Earth Are About Equal to That of a Solid Ball of Iron.

The Technology scientists next fixed two lead balls, weighing about ten pounds each, upon a frame, so that they were immovable. The frame was placed about the hanging balls in such a way that each of the lead balls was brought close to the freely swinging spheres.

The lead balls, exercising a slight but definite power of attraction over the hanging brass ones, moved them slightly, almost impercentibly. The supporting thread was twisted, ever so little, and the spot of light on the wall opposite moved almost a yard's length as a result.

Not a large force. Indeed, when delicate calculations had estimated its power it was found to be equal to the weight of an atom of hair just one one-hundredth thousandth of an inch long. But this force, slight as it was, had been sufficient to reveal the earth's weight. From this point it was a comparatively simple matter of mathematics.

The Technology professors knew the weights of the two sets of balls; they knew the amount of power which the lead balls exercised over the brass; they knew the power which the earth exercised over the lead—that was their weight. Also they knew that the gravitational attraction of one body over another depends directly upon the comparative sizes of the bodies involved.

What, then, more simple than to cadculate the earth's mass? It was a simple equation, of which three parts already were known. The scientists calculated the value of the fourth part and gained the answer—6,000,000,000,000,000,000,000 tons.

Over and over again the experiment was tried. Outside influences, the vibration caused by subway and surface trains, the quivering of the great Technology building from its own mechanical laboratories, affected the delicate mechanism somewhat.

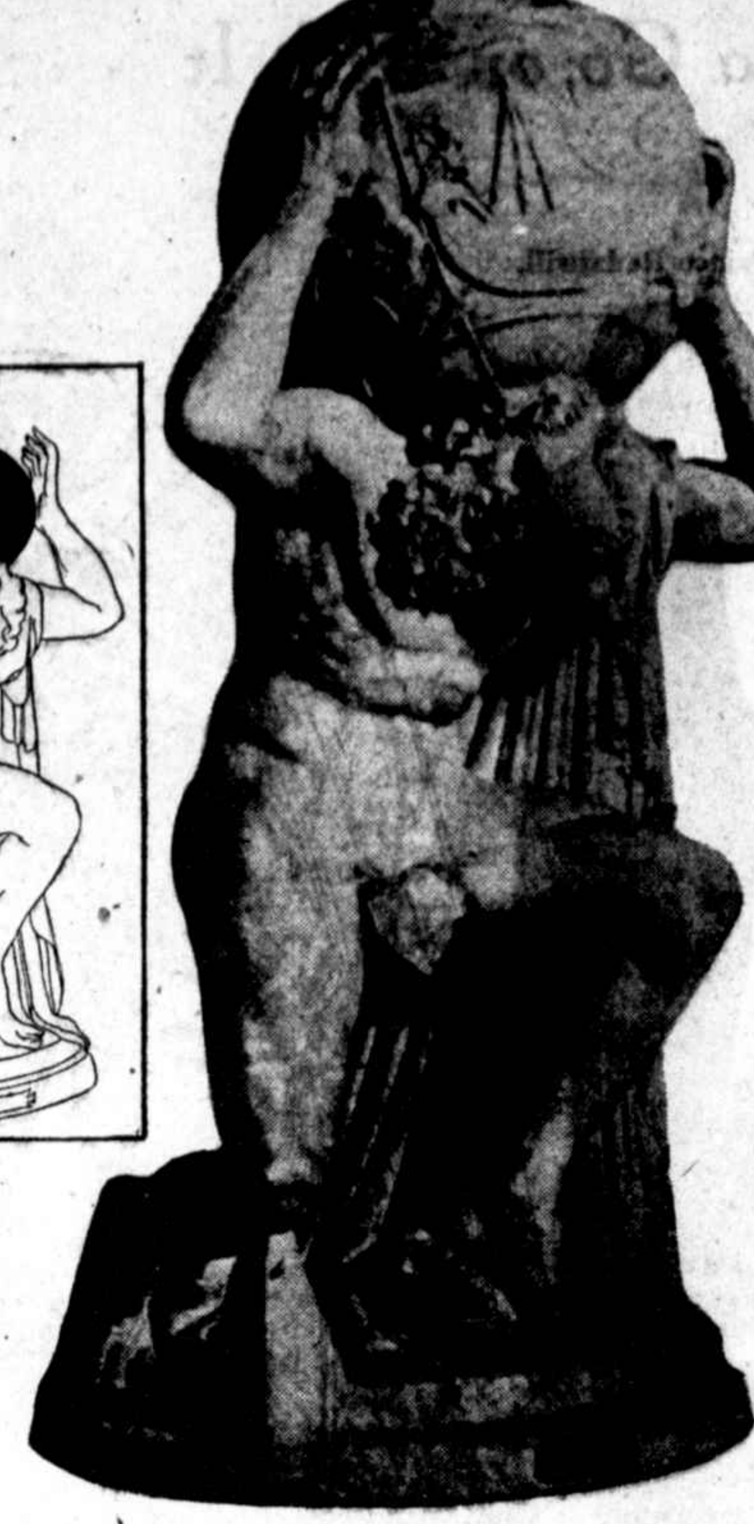
But when the experiment had been performed a score of times and the average of them all was taken Professor Derr knew that his result was approximately correct. A million tons one way or the other was a small matter considering the huge figures involved.

The earth is not the only planet from which scientists have wrenched the secret of weight. Other heavenly bodies have been accurately weighed, through application of the same simple law of gravitation.

For hundreds of years it was known that the orbits of the planets were irregular, changing abruptly in many cases as the flying worlds came within the gravitational attraction of some other wanderer of the skies. Astronomers, after years of delicate observation and intricate calculation in which they considered the forces required to move these bodies from their paths, were able to give to the world the approximate weight of the sun, the moon and a few others of the nearer heavenly bodies.

The distant stars alone have defied the scales of science. Too far removed from us for the power of attraction to be felt, too vast to be affected by flying planets, their weight cannot be determined.

Astronomers can tell us the size but not the weight of these stars, some of which are blazing gases and some molten rock and metal.



Atlas Holding the Earth on His Back—the Old Mythological Explanation of How the Earth Was Sustained in Space.

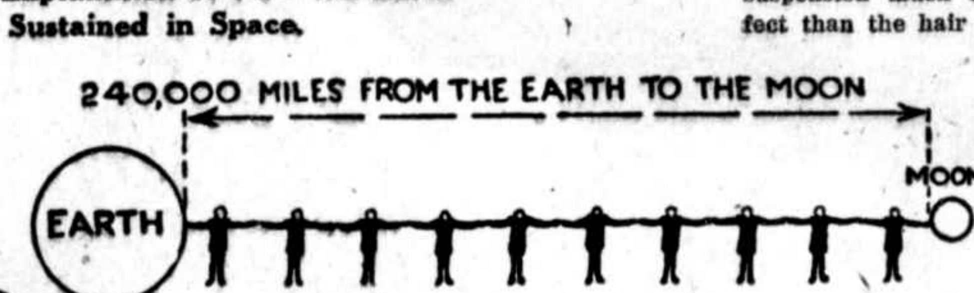
Professor Louis E. Derr, of the Massachusetts Institute of Technology, Who Weighs the Earth Every Year as a Routine Part of His Laboratory Class Work in Physics.

Cavendish, the great English chemist and physicist, was the first to undertake to weigh the earth. An apparatus devised by the Rev. John Mitchell was adopted by Cavendish for his experiments after he had made several great improvements on it.

The theory of this instrument was developed from studies of the vibrations of the pendulum, whose motive power is that of gravity. The velocity was very accurately measured by counting the rate and distance of the swings in a day; from this was calculated the power of attraction of the earth.

The pendulum idea was then extended to the attraction of small masses of known weight. It was observed that as many times as a ball weighs less than the earth, so many times more slowly will a pendulum be moved by a ball.

To adapt the idea successfully it was necessary to neutralize the pull of the earth. So Cavendish laid a perfectly turned horizontal bar on the point of an upright needle so that it balanced true. It was free like the needle of a compass to turn to the right or to the left. On the ends of this bar were fastened two perfectly equal balls of accurately measured weight.



A Man Powerful Enough to Hold the Earth on His Shoulders Would Be So Large That Ten Men Like Him, With Arms Outstretched, Would Reach from the Earth to the Moon.

In this way the bar still balanced, and though the earth was not at all suspended, the pull of the earth was made ineffective for the purpose of the experiment. Cavendish then placed heavier balls of known weight near the small spheres, but not touching. These were attracted toward the larger bodies; then when the spheres were gently pulled away they were drawn back upon being released and vibrated much as a pendulum would.

This force was exceedingly small, and the vibrations very slow, but they were counted and measured, and the results compared with those of the vertical pendulum. From this data the rest is a simple problem in proportion.

It is a very delicate experiment. The least variation in the temperature, resulting in a contraction or an expansion of the balls, or the uneven distribution of the matter used in the construction of the room or building where the experiment is carried on will upset the results.

Even the observer's own movements set the air in motion, so that the air must be kept stagnant. Cavendish figured the earth's weight to be 6,069,094,272 billions of tons in 1869—a result very close to that secured in Cambridge the other day. This made the specific gravity of the earth about 5.4, or in other words the earth weighed, according to his figures, about five and a half times the weight of an equal body of water.

Sir Isaac Newton Experimenting With Rays of Light in His Laboratory. Newton Discovered the Principle Which Enabled Science to Calculate the Weight of our Earth.

The apparatus used in the experiments at the Massachusetts Institute of Technology is an improvement in many ways and it is therefore presumed that its results are far more accurate. For one thing the use of the delicate quartz threads gives a suspension much more nearly perfect than the hair employed by the English scientist. Then, too, the Technology experts have succeeded in minimizing the influences of temperature and other disturbing factors better than Cavendish was able to do.

To try to form a conception of the six sextillions of tons which the earth weighs is an interesting speculation. But it is one that imposes a severe tax upon even the most vivid imagination.

Ancient mythology used to picture the earth as borne on the shoulders of the giant Atlas. As modern scientific knowledge points out, however, the proportions which the ancients gave to the giant and the globe on his shoulders were entirely incorrect.

The average density of the earth is estimated as about the same as that of iron ore. A man of average size and strength can carry on his shoulders a globe of iron ore measuring a foot in diameter. The theoretical giant capable of bearing the earth on his shoulders would bear the same proportion to the earth that a six foot man does to the iron globe.

A scientist with a turn for curious speculation estimates that the man capable of lifting the earth on his shoulders, as Atlas was supposed to have done, would be so colossal in size that ten men like him, with arms outstretched, would form a human chain long enough to stretch the 240,000 miles from the earth to the moon.

The total amount of coal produced since man learned how to mine is only about 10,000,000,000 tons—and that gigantic heap of coal is as but a featherweight in comparison with twelve septillion pounds at which the earth tips the scales of science.

Although usually pictured by painters and sculptors as bearing the earth on his shoulders, the Atlas of mythology was really supposed to support the heavens. This burden, it was declared, had been imposed on him as a punishment for his rebellion against Zeus. Later this story was elaborated to make Atlas a leader of the Titans in their war against the gods.

Atlas was always located in the far west, beyond the horizon; finally he was localized in northwestern Africa. There he was a king, rich in flocks, owner of the gardens of the Hesperides.

Sir Isaac Newton. An Old Painting by Sir Godfrey Knowler.

Atlas, as bearer of the heavens, appears in early Greek art on vases and reliefs in connection with Hercules's search for the apples of the Hesperides. In statuary Atlas is first represented by the Pergamene school; he is portrayed as carrying the heavens on the terrestrial globe. The plural, Atlantes, is applied in architecture to male figures serving as columns.

In consequence of the ancient views, which made the vault of heaven rest on solid pillars or other supports, the name "Atlas," originally mythological and cosmogonic, was introduced into geography; it was given to a hill in northwest Africa. Mercator, in the sixteenth century, applied the name "Atlas" to a collection of maps, probably because the figure of Atlas supporting the heavens had been given on the title pages of such works.

As depicted by mythology, Atlas was what seemed to the eyes of the ancients the most marvellous of giants. But since science has learned how to put the earth on scales and register its weight, we know that old Atlas was a mere pygmy compared with the sort of creature who would really be capable of supporting on his shoulders this globe of ours.

The quartz threads used in weighing the earth at the Massachusetts Institute of Technology are probably the smallest ever manufactured. They are made by melting the ends of quartz crystals together and then pulling the crystals apart. In this manner quartz can be drawn even finer than platinum, the most ductile of the metals.

"Determining the mass of the earth is one of the most delicate and beautiful experiments in physics," said Professor Derr, who has charge of the earth-weighing experiments at Cambridge. "Because of its delicacy it is an unusual problem to be given a body of college students. There is some difficulty encountered from the fact that Boston, and particularly that part of it which is built upon 'made' land in the Back Bay, is constantly shaking and trembling, a condition which makes itself felt immediately in the laboratory. The experiment as it is performed to-day at the institute is highly satisfactory, however, and extremely interesting."